

Bhopal and Bagasse: Understanding Combustion Using Mathematics

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Outline

- What is ignition?
- Describe two examples
 - Bhopal
 - Bagasse
- Mathematics of combustion
- Analytic tools
- Outcomes

What is ignition?

- Semenov
 - constant temperature
- Frank-Kamenetskii
 - temperature gradient
 - thermal runaway
 - chain reactions

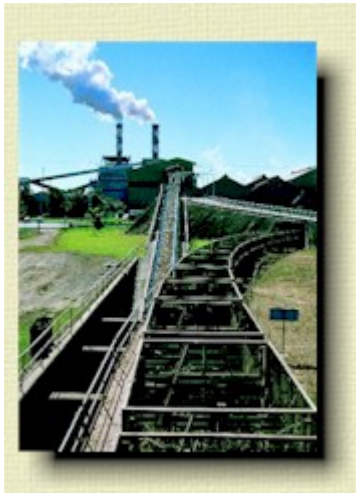
Bhopal Incident 1984

- Methyl isocyanate
- Water intrusion
- Pressure explosion



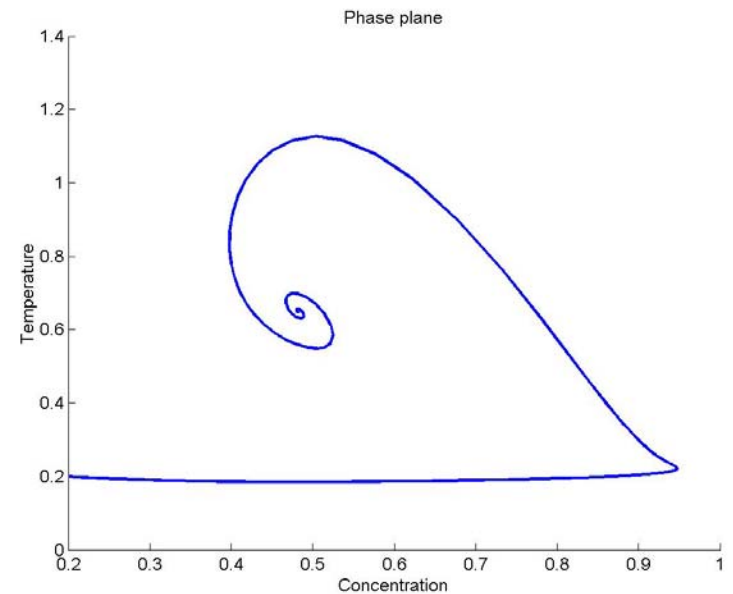
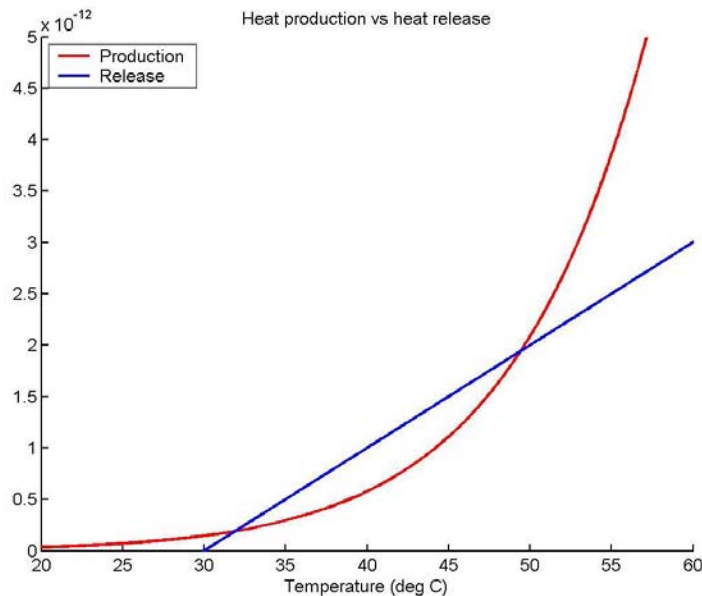
Bagasse

- Sugarcane residue
- Large piles
- Moisture content



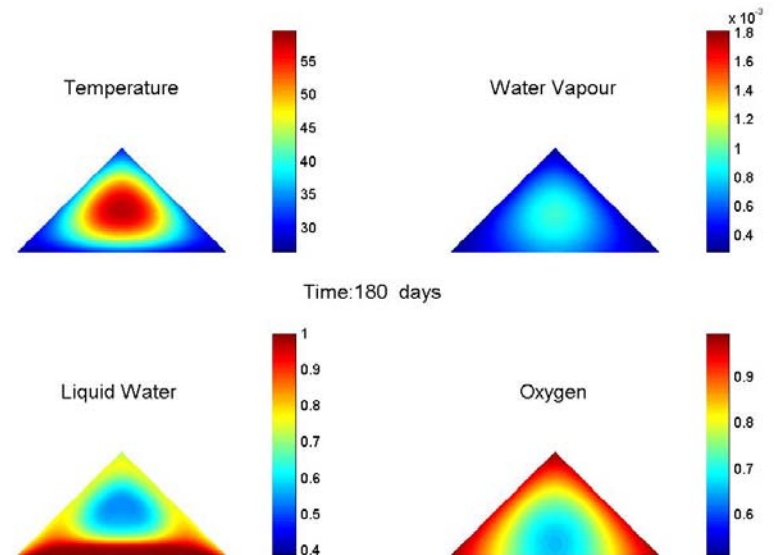
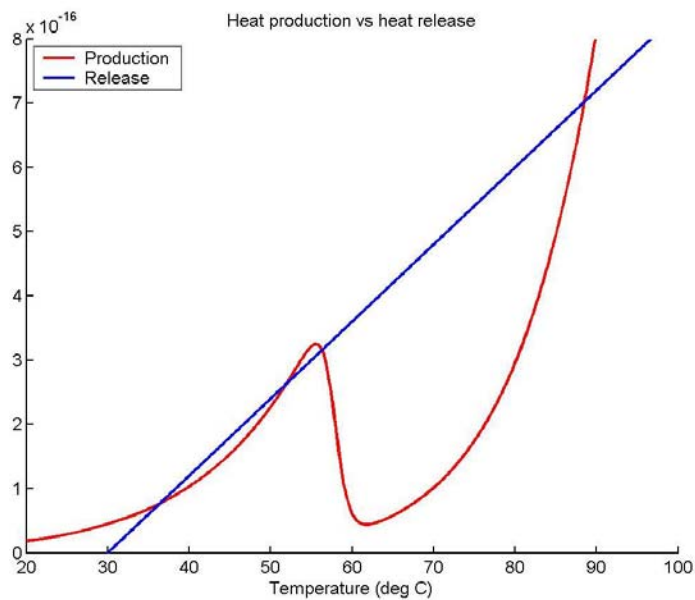
Modelling

- Heat generation: $\text{Exp}(-1/\text{Temperature})$
- Heat loss: Newtonian cooling; linear
- Bhopal example



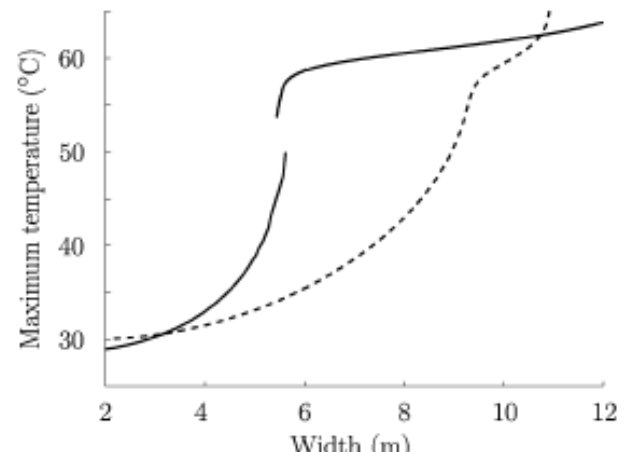
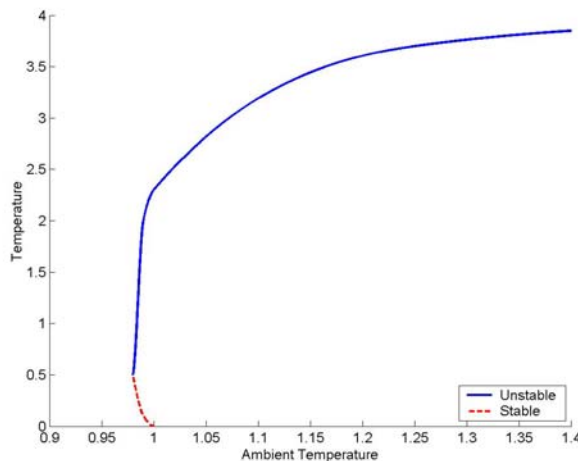
Modelling

- Bagasse
 - Geometry



Dynamical Systems Theory

- Bifurcation analysis
- Bhopal: Ambient temperature
 - Stable regimes can yield high temperature excursions leading to an explosion
- Bagasse
 - Width
 - Ignition before turning point



Conclusions

- Safety/risk analysis
 - Sensitivity analysis = Bifurcation analysis
- Simple physical models
 - nonlinear
 - capture/simulate behaviour and give further insight
- Chemical reactor design and storage technology